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ABSTRACT

The six new robotics and automated systems specialty courses developed by the Robotics/Automated Systems Technician (RAST) project are described in this publication. Course titles are Fundamentals of Robotics and Automated Systems, Automated Systems and Support Components, Controllers for Robots and Automated Systems, Robotics and Automated Systems Interfaces, Robotics/Automated Systems at Work, and Automated Work Cell Integration. This information is included for each course: a course description, course outline with number of classroom and laboratory hours per week, laboratory activities, and a list of student competencies. Each course is further amplified by the inclusion of suggested modules and module outlines (an introduction, topic outline, and a list of instructional objectives) to support that course. The module outlines could be used as a guide by instructors wishing to write their own text material and laboratory manuals. (YLB)

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OUTLINES FOR NEW COURSES AND MODULES

Project No. 051MH30009

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TASK ANALYSIS AND DESCRIPTIONS OF REQUIRED JOB COMPETENCIES OF ROBOTICS/AUTOMATED SYSTEMS TECHNICIANS

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Center for Occupational Research and Development

Waco, Texas

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OFFICE OF VOCATIONIAL AND ADULT EDUCATION

FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS
Classroom/Lab hrs/wk 2/3

COURSE DESCRIPTION

This course introduces the student to robotics and automated systems and their operating characteristics. Topics to be covered include robotics principles of operation and work envelopes. Students will learn the various coordinate systems and how hydraulic, pneumatic and electromechanical systems function together as a system. Other subjects to be covered include servo and nonservo controls, system capabilities and limitations, and safety. Robot tooling will be investigated including welders, grippers, magnetic pickups, vacuum pickups, compliance devices, adhesive applicators, and paint sprayers.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Introduction to Robotics and Automated Systems	2	3
A. Description of a System		
B. Definitions		
1. Robots		
2. Automation		
C. Elements of Automation		
1. CAD (CADD)		
2. CAM		
3. CAD/CAM		
4. CAE		
5. CIM		
D. Robot Components		
1. Manipulator		
2. Power supply		
3. Controller		
4. Transducers		
II. Robotics/Automated Systems Hazards and Safety Requirements	2	
A. Three Axioms		
B. Three Laws		
C. Robot Hazards (risk identification)		
D. Regulations		
1. NFPA		
2. OSHA		
3. NEMA		
4. JIC		
5. NMTBA		
6. IEEE		
7. NEC		
8. ANSI		

		Student Contact Hours Class	Laboratory
	E. Mental Attitude		
	1. Cleanliness		
	2. Neatness		
III.	Robotic Operating Parameters	4	6
	A. Interpreting Manufacturer's Specifications		
	1. Accuracy/repeatability		
	2. Coordinate system		
	3. Speed		
	4. Arm geometry		
	B. Degrees of Freedom		
	1. Definition		
	2. Robot/arm		
	3. Wrist/tool		
	C. Payload		
	1. Mass		
	2. Limitations		
	3. Radius (cg distance from mount surface)		
	4. Moment of inertia		
IV.	Robot Programming Characteristics	4	6
	A. Reference Planes of Motion		
	1. Tool control path		
	2. Robot's coordinate system		
	B. Programming Characteristics		
	1. Language		
	2. High/med/low technology		
	C. Path Control		
	1. Point-to-point		
	2. Controlled path		
	3. Continuous path		
V.	Robot Structural Systems	2	3
	A. Mechanical		
	1. Support		
	2. Structural		
	3. Arm-motion control		
	B. End-of-Arm Tooling		
	1. Tooling		
	2. Compliance devices		
	3. Applications		
	C. Grippers		
	1. Parallel motion		
	2. Angular motion		
	3. Special		
VI.	Robot Drive Systems	2	6
	A. Electrical		
	1. Power		
	2. Control		
	3. Servo		
	4. Stepper motors		

	Student Contact Hours	
	Class	Laboratory
B. Hydraulic		
1. Pumps		
2. Actuators		
3. Valves		
C. Pneumatic		
1. Pumps		
2. Actuators		
3. Valves		
VII. Robot Control and Feedback Systems	4	6
A. Control		
1. Open loop		
2. Closed loop		
B. Transducers		
1. Discrete		
2. Analog		
C. Relative and Absolute Positioning		

STUDENT LABORATORIES

I. Measure Robot Physical Characteristics
Coordinate systems
Speed of operation
Payloads
Work envelope

II. Identify Robot's Path Control Characteristics and Reference Planes
Point-to-point
Control path
Continuous path

III. Program Robots and Automated Systems
Teach pendant
Lead through
Off line
Post processor

IV. Program/Operate End-of-Arm Tooling
Grippers
Vacuum pickups
Magnetic pickups

V. Describe and Operate Drive System
Mechanical
Electrical
Hydraulic/pneumatic

VI. Identify Major Systems
Mechanical
Electrical
Hydraulic
Pneumatic
Controls
Sensors
Servos/nonservos
End-of-arm tooling

STUDENT COMPETENCIES

Upon completion of this course students will be able to:

1. Measure robot performance (distance, positioning, accuracy and repeatability).
2. Specify the robot coordinate system.
3. Operate the following equipment.
   a. End-of-arm tooling
   b. Grippers
   c. Magnetic pickups
   d. Vacuum pickups
   e. Compliance devices
4. Identify major systems of a robot.
5. Describe robot drive system operation.
6. Describe mobility of an industrial robot.
7. Identify a robot's work envelope.
8. Be conversant in robot technology.
9. Demonstrate knowledge of safety requirements for working around robots.
10. Specify safety considerations for personnel, work area, operations and machines.

FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS

MODULE FR-01 Introduction to Robotics and Automated Systems

INTRODUCTION

This module introduces the students to the concepts of robotics and automation. They will learn that systems and subsystems work together as part of a total robotic/automated system.

MODULE OUTLINE

I. Description of a System
Breakdown System into Subsystems

II. Definitions
- A. Robots
  - 1. RIA
  - 2. JIRA
- B. Automation

III. Elements of Automation
- A. CAD(CADD)
- B. CAM
- C. CAD/CAM
- D. CAE
- E. CIM

IV. Robot Components
- A. Manipulator
  - 1. Arm
  - 2. Tooling
- B. Power Supply
  - 1. Electric
  - 2. Hydraulic
  - 3. Pneumatic
- C. Controller
  - 1. Nonservo
  - 2. Servo
- D. Sensors
  - 1. Contact
  - 2. Noncontact

INSTRUCTIONAL OBJECTIVES

Upon completion of this module students will be able to:

1. Describe how several subsystems function together as part of a total system.
2. Define a robot (RIA and JIRA).
3. Describe the function of a robot arm.
4. Define the following terms:

arm	pneumatic
contact sensor	servo
noncontact sensor	nonservo
memory	CAD/CAM
hydraulic	

5. Identify the major components of a hydraulic system.
6. Identify the major components of a pneumatic system.
7. Describe the concept of automation.

FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS

MODULE FR-02 Robotics/Automated Systems Hazards and Safety Requirements

INTRODUCTION

Students in this module learn the ideals of safety. They are shown the hazards involved with robots and normal production facilities. As part of the lab, students will assemble and operate simple safety and warning systems.

MODULE OUTLINE

I. Three Axioms
   A. If the robot is not moving, do not assume it is not going to move.
   B. If the robot is repeating a pattern, do not assume it will continue.
   C. Maintain respect for what a robot is and what it can do.

II. Three Laws (Asimov's)
   A. A robot must not harm a human being, nor through inaction allow one to come to harm.
   B. A robot must always obey human beings, unless that is in conflict with the first law.
   C. A robot must protect itself from harm, unless that is in conflict with the first and/or second law.

III. Robot Hazards (risk identification)
   A. Speed of Operation
   B. Pinch Points
   C. Safety Shields
   D. Warning Labels

IV. Regulations/Codes
   A. NFPA
   B. OSHA
   C. NEMA
   D. JIC
   E. NMTBA
   F. AGMA
   G. IEEE
   H. NEC
   I. ANSI

V. Mental Attitude
   A. Cleanliness
   B. Neatness

INSTRUCTIONAL OBJECTIVES

Upon completion of this module students will be able to:

1. Identify six safety hazards associated with robots.
2. State three axioms of safety for working around robots.
3. State Asimov's three laws of robot safety.
4. List two examples of regulations for each of the following:

NFPA	OSHA	NEMA	JIC	ANSI
NMTBA	AGMA	IEEE	NEC	

LAB ACTIVITIES

1. Design, assemble, and operate an electrical safety circuit that will interrupt a robot power supply when a gate is opened.
2. Design safety barriers for three industrial robots.

FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS

MODULE FR-03 Robotic Operating Parameters

INTRODUCTION

This module describes the geometric and operational characteristics of a robot. Students will learn four coordinate systems, degrees of freedom and payload parameters.

MODULE OUTLINE

I. Manufacturer's Specifications
   - A. Accuracy/Repeatability
   - B. Coordinate System
     1. Cartesian
     2. Spherical
     3. Cylindrical
     4. Jointed spherical
     5. Tool center point
   - C. Power Supply
     1. Electric
     2. Hydraulic
     3. Pneumatic
   - D. Motion
     1. Speed
     2. Momentum
     3. Acceleration
   - E. Arm Geometry
     1. Telescopic
     2. Articulated

II. Degrees of Freedom
   - A. Definition
   - B. Robot/Arm
   - C. Wrist/Tooling

III. Payload
   - A. Mass
   - B. Limitations
   - C. Radius (cg distance from mount surface)
   - D. Moment of Inertia

INSTRUCTIONAL OBJECTIVES

Upon completion of this module the student will be able to:

1. Identify and explain the four coordinate systems that describe robot movements.
2. Describe the degrees of freedom of a robot.

3. Calculate payload limitations.
4. Given a robot, identify its degrees of freedom and coordinate system.
5. Compare and evaluate manufacturer's specification for selected robots.

LAB ACTIVITIES

1. Measure the relative positions of three points in space (using one as the origin) using cartesian, cylindrical, and spherical coordinates.
2. List the degrees of freedom of five different robots.
3. Plot a curve showing payload mass versus distance from mounting surface.

FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS

MODULE FR-04 Robot Programming Characteristics

INTRODUCTION

This module introduces the student to the concept of reference planes, the characteristics of programming robot motion, and the paths of motion of a robot arm. Students will do limited programming and operating of robots.

MODULE OUTLINE

I. Reference Planes of Motion
   A. Tool Control Path
   B. Robot's Coordinate System

II. Programming Characteristics
   A. Introduction to Languages
      1. VAL
      2. APT
      3. COMPACT II
      4. Other
   B. Programming Methods
      1. Off-line
      2. Teach pendant
      3. Walk through
      4. Lead through
   C. High/med/low technology
      1. Servo/nonservo
      2. Path of motion

III. Path Control
   A. Point-to-Point
      1. Controlled path
      2. Noncontrolled path
   B. Continuous Path

INSTRUCTIONAL OBJECTIVES

Upon completion of this module students will be able to:

1. Define reference plane.
2. Describe the purpose of a (machine) program.
3. List and describe the three types of robot arm-movement
4. Create simple programs for robot arm motion control paths.
5. Explain the term "tool control path."
6. Describe the difference between high, medium, and low technology as applied to industrial robots.

LAB ACTIVITIES

1. Program robots that use cartesian, cylindrical, or spherical coordinates.
2. Program a robot using the tool path pointing system.
3. Program a robot using a teach pendant.
4. Program robots using point-to-point, control path, and continuous path.

FUNDAMENTALS OF ROBOTS AND AUTOMATED SYSTEMS

MODULE FR-05 Robot Structural Systems

INTRODUCTION

This module describes the mechanical and structural characteristics of a robot. Students will learn the mechanical aspects of various support and operational systems and end-of-arm tooling.

COURSE OUTLINE

I. Mechanical
   A. Support
   B. Structural
   C. Arm-Motion Control

II. End-of-Arm Tooling
   A. Tooling
      1. Welders
      2. Painters
      3. Nut-drivers
      4. Special
   B. Compliance Devices
      1. Active
      2. Passive
   C. Applications
      1. Magnetic pickups
      2. Vacuum pickups
      3. Mandrels
      4. Pneumatic fingers

III. Grippers
   A. Parallel Motion
   B. Angular Motion
   C. Special

INSTRUCTIONAL OBJECTIVES

Upon completion of this module students will be able to:

1. Describe and sketch the operation of a four-bar linkage.
2. Program and operate robot arms that are equipped with either welders or painters.
3. Program and operate vacuum and magnetic pickups.
4. Describe the difference between parallel and angular grippers.
5. Explain the difference between active and passive compliance devices.
6. Determine the maximum weight that can be lifted with a specific vacuum or magnetic pickup.
7. Identify the applications which should use parallel gripper motion.
8. Identify the applications which should use angular gripper motion.

LAB ACTIVITIES

1. Sketch and diagram the operating elements of a robot.
2. Mount a welder or paint gun to a robot arm.
3. Install/remove a remote center compliance device.

FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS

MODULE FR-06 Robot Drive Systems

INTRODUCTION

This module describes robot drive systems and their control. Students will operate electrical, pneumatic, and hydraulic power and control systems.

MODULE OUTLINE

I. Electrical
   A. Power
   B. Control
   C. Servo
      1. AC
      2. DC
   D. Stepper Motors

II. Hydraulic
   A. Pumps
      1. Fixed displacement
      2. Variable displacement
   B. Actuators
      1. Linear
      2. Rotary
   C. Valves

III. Pneumatic
   A. Pumps
      1. Fixed displacement
      2. Variable displacement
   B. Actuators
      1. Linear
      2. Rotary
   C. Valves

INSTRUCTIONAL OBJECTIVES

Upon completion of this module the student will be able to:

1. Describe the operation of servo motors and stepper motors in robot drive systems.
2. Describe the function of each component in a hydraulic and/or pneumatic system of a robot.
3. Operate robot drive systems.
4. Calculate the mechanical advantage and speed ratio of gear trains.
5. Explain the difference between fixed- and variable-displacement pumps.
6. Explain the function/purpose of a relief valve in a hydraulic or pneumatic system.
7. List the advantages and disadvantages of electric, hydraulic, and pneumatic drive systems.

LAB ACTIVITIES

1. Operate robots equipped with servo control systems.
2. Operate robots equipped with stepper motors.
3. Operate robots equipped with hydraulic cylinders and motors.

FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS

MODULE FR-G7 Robot Control and Feedback Systems

INTRODUCTION

This module describes the methods used to sense robot positions and how this information is fed back to the controller. Students will observe how fed-back information affects controller operation.

MODULE OUTLINE

I. Control
   A. Open Loop
   B. Closed Loop

II. Sensors
   A. Discrete
      1. Thermistor
      2. Photodiode
      3. Limit switch
      4. Hall effect
      5. Encoder
   B. Analog
      1. Piezoelectric
      2. Thermistor
      3. Phototransistor
      4. Strain gage rosette
      5. Thermocouple
      6. Acoustic
      7. Eddy current
      8. Potentiometer
      9. Resolver
      10. Tachometer generator

INSTRUCTIONAL OBJECTIVES

Upon completion of this module students will be able to.

1. Describe two methods of controlling robot motion.
2. Identify five types of sensors in robotic systems
3. Describe the difference between servo and nonservo systems
4. Explain the purpose of feedback systems.
5. Explain the difference between open and closed loop.
6. Describe the following sensors:

Thermistor	Photodiode	Limit switch
Hall effect	Piezoelectric	Phototransistor
Thermocouple	Acoustic	Strain gage rosette
Eddy current	Potentiometer	Tachometer generator
Resolver		

7. Describe an open-loop control system.
8. Describe a closed-loop control system.

LAB ACTIVITIES

1. Operate open-loop control systems.
2. Operate closed-loop control systems.
3. Observe discrete device performance characteristics.
4. Observe analog device performance characteristics.
5. Identify the sensors installed on a robot.

AUTOMATED SYSTEMS AND SUPPORT COMPONENTS
Classroom/Laboratory hrs/wk 2/6

COURSE DESCRIPTION

Students learn the concepts of production--mass production, batch processing, and job shopping. They also learn how identical support components are applied to different types of automated manufacturing. Proper orientation of parts will be examined in the laboratory. Also, sensor performance will be compared to manufacturer's data.

COURSE OUTLINE

	Student Contact Hours Class	Laboratory
I. Introduction to Types of Manufacturing	2	0
A. Mass Production		
1. Large volume		
2. Hard or fixed automation		
3. Single-purpose machines/transfer lines		
B. Batch Processing		
1. Small volumes		
2. Job shop		
3. Flexible automation		
4. Group technology		
C. Job Shopping		
1. Limited production		
2. Flexible manufacturing (if large or expensive items)		
II. Parts Movers	4	15
A. Parts Feeders		
1. Bowl feeders		
2. Hoppers		
3. Gravity feeders		
B. Material Handlers		
1. Conveyors		
2. Wire-guided vehicles		
3. Cranes		
4. Lift, carry, and shuttle-type transfer devices and systems		
5. Power-and-free versus synchronous		
6. Walking beams		
III. Jigs and Fixtures	4	12
A. Free-Effort Fixtures		
B. Parts Orientation		
C. Fixture Optimization		

	Student Contact Hours	
	Class	Laboratory
IV. Positioners A. Electrical B. Pneumatic C. Hydraulic D. Index tables	4	15
V. Sensors (Direct Reading/Discrete [Single-Function] Devices) A. Limit Switches B. Position Indicators C. Level Indicators D. Tactile E. Pressure F. Temperature	4	18

STUDENT LABORATORIES

I. Observe and Describe Three Types of Manufacturing
Take field trips and write reports describing observed manufacturing operations
Separate ten parts according to common manufacturing operations (Group Technology)

II. Set Up Part Feeders
Operate rotary hopper
Operate bowl feeders
Determine parts presentation requirements

III. Operate the Following Types of Material Handlers
- Conveyors
- Wire-guided vehicles
- Gravity feeders

IV. Evaluate the Following Types of Sensors
- Limit switch
- Photoelectric
- Tactile
- Proximity
- Temperature
- Pressure
- Flow

V. Operate the Following Positioners and Work Holders
- Hydraulic
- Electric
- Pneumatic
- Mechanical
- Index tables

VI. Set Up and Operate the Following Energy Control Devices
- Switches
- Relays
- Valves
- Servo
- Nonservo

VII. Evaluate Applications of the Following Types of Actuators
- Cylinders
- Rotary devices
- Stepper motors
- Mechanical
- Springs
- Solenoids

VIII. Assemble and Study Mechanical Positioners Operated by the Following
- Four-bar linkages
- Geneva mechanisms
- Links
- Gears/pulleys
- Cam and follower
- Walking beams

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

1. Program stepper motors.
2. Install, adjust, troubleshoot and repair or replace tactile and video sensors.
3. Describe the application of mechanical linkages/gears to a robotic work cell.
4. Perform electrical adjustments on servo power amplifiers.
5. Describe the application of hydraulic, electric or pneumatic positioners and sensors to a flexible cell.

MODULE AS-01 Types of Manufacturing

INTRODUCTION

This module presents the three basic methods used by manufacturers to produce goods--continuous (mass) production, batch processing, and job shopping. Students will learn the criteria used in selecting the correct process and the advantages and disadvantages of each.

MODULE OUTLINE

I. Mass Production
   - A. Large Volume
   - B. Hard or Fixed Automation
   - C. Single-Purpose Machines/Transfer Lines

II. Batch Processing
   - A. Small Volumes
   - B. Flexible Automation
   - C. Group Technology

III. Job Shop
   - A. One or Two of a Kind
   - B. Flexible Automation (if very expensive or large)

OBJECTIVES

Upon completion of this module students will be able to:

1. Describe the characteristics of continuous (mass) production, batch processing, and job shopping.
2. Evaluate a product and determine the correct manufacturing technique for it.
3. Draw a material flow diagram, from receiving to shipping, for one part produced in a factory using mass production techniques.
4. Define the term "flexible automation."
5. Explain the meaning of "group technology."
6. Describe a manufacturing operation using single-purpose machines and transfer lines.
7. List the advantages and disadvantages of mass production, batch processing, and job shop production.

MODULE AS-02 Parts Movers

INTRODUCTION

This module introduces students to various types of equipment that supply parts/subassemblies to automated machine tooling. Students will evaluate methods of parts orientation to facilitate transfer to subsequent machines. Students will also learn the characteristics of systems that move large parts and/or large numbers of parts.

MODULE OUTLINE

I. Parts Feeders
   - A. Bowl Feeders
   - B. Vibratory Feeders
   - C. Feed Rate
   - D. Gravity Feeders

II. Material Handlers
   - A. Conveyors
   - B. Wire-Guided Vehicles
   - C. Cranes
   - D. Lift, Carry and Shuttle-type Transfer Devices/Systems
   - E. Power-and-Free versus Synchronous
   - F. Walking Beam

OBJECTIVES

Upon completion of this module students will be able to:

1. Set up equipment to supply parts to subsequent machines.
2. Set up a bulk feeder to supply parts at a specified rate.
3. List the operating characteristics/constraints of:
   - a. Conveyors
   - b. Wire-guided vehicles
   - c. Gravity feeders
   - d. Lift, carry and shuttle-type transfer devices/systems
4. Explain the difference between a "part" and a "subassembly."
5. Define the term "part orientation."
6. Explain the difference between "parts feeder" and "material handler."
7. Describe an appropriate application of a bowl feeder.
8. Describe an appropriate application of a vibratory feeder.
9. Define the term "feed rate."
10. Describe the operation of a wire-guided vehicle.
11. Describe an appropriate application of a "gravity feeder."
12. Define the term "conveyor."
13. Assemble a conveyor system used to supply parts to a robot.
14. Set up and operate a vibratory feeder.

LAB ACTIVITIES

1. Assemble parts feeders and/or material-handling devices to supply parts to a robot.
2. Set up and operate a vibratory feeder.
3. Build a fixture to hold a workpiece in a specified orientation.
4. Analyze and determine optimum fixturing for manufacturing two parts.

AUTOMATED SYSTEMS AND SUPPORT COMPONENTS

MODULE AS-03 Jigs and Fixtures

INTRODUCTION

This module describes methods and equipment used to hold parts in a specific orientation. Students will assemble jigs and fixtures and use them to orient parts properly for subsequent operations.

MODULE OUTLINE

I. Free-Effort Fixtures
   A. Description
   B. Parts Orientation Determination
   C. Part Holder

II. Parts Orientation
   A. Constraints of Part
   B. Constraints of Operation
   C. Part Design

III. Fixture Optimization
   A. Maximum Number of Parts
   B. Economic Considerations
   C. Position Optimization

OBJECTIVES

Upon completion of this module students will be able to:

1. Describe the purpose of jigs and fixtures.
2. Analyze fixtures for economic improvement.
3. Sketch parts in a specific orientation.
4. Sketch jigs/fixtures to hold a part in a specific orientation.

LAB ACTIVITIES

1. Design and assemble a fixture for holding parts to be welded.
2. Design and assemble a fixture to hold parts in the correct orientation for a robot to pick them up.
3. Design and assemble a fixture to receive parts from a robot.
4. Design a shipping fixture to maximize the number of parts stackable in one layer of a shipping carton.

MODULE AS-04 Positioners

INTRODUCTION

This module presents the concept of work positioners--devices that hold a workpiece in a specific orientation while it is being worked on. Students will operate positioners to hol workpieces in a specific orientation.

MODULE OUTLINE

I. Application of Positioners
   - A. Welding
   - B. Machining
   - C. Painting
   - D. Assembly

II. Electrical
   - A. Stepper Motors
   - B. Servo Motors
   - C. Solenoids

III. Pneumatic
   - A. Cylinders
   - B. Motors
   - C. Servos

IV. Hydraulic
   - A. Cylinders
   - B. Motors
   - C. Servos

V. Mechanical
   - A. Geneva Mechanisms
   - B. Ball Screw
   - C. Bell Crank
   - D. Four-bar Linkage
   - E. Cam and Follower
   - F. Walking Beams

OBJECTIVES

Upon completion of this module students will be able to:

1. Sketch the correct way to hold a workpiece.
2. Identify and sketch the correct orientation for a specific part while it is being worked on.
3. Describe how actuators and mechanisms are used to accomplish 1 and 2.
4. Calculate the maximum force achievable by a cylinder.
5. Troubleshoot and repair servo and stepper motors.
6. Set up work holders to hold two pieces to be welded.

7. Define the term "work positioner."
8. Explain the function performed by a servo motor.
9. Design, assemble and operate an electrically-operated work positioner.
10. Design, assemble and operate a hydraulically-operated work positioner.

LAB ACTIVITIES

1. Design, assemble and operate an electrically-operated work positioner.
2. Design, assemble and operate a hydraulically-operated work positioner.

MODULE AS-05 Sensors (Direct-Reading/Discrete [Single-Function] Devices)

INTRODUCTION

This module discusses seven discrete sensors used in robotics and automated systems. Students will test each type of sensor and compare its operating characteristics with manufacturer's specifications.

MODULE OUTLINE

I. Contact Sensors
   - A. Tactile
   - B. Limit Versus Proximity Switches

II. Noncontact Sensors
   - A. Vision
   - B. Magnetic
   - C. Optoelectric
     1. Direct
     2. Retroreflective
     3. Diffused
     4. Specular
   - D. Eddy Current

III. Process Sensors
   - A. Pressure
   - B. Temperature
   - C. Level
   - D. Flow

OBJECTIVES

Upon completion of this module students will be able to:

1. Identify the correct application of five different sensing devices.
2. Describe a discrete device.
3. Test and compare sensor performance with manufacturer's specifications.
4. Install, calibrate, adjust limit switches, level indicators, and pressure and temperature indicators.
5. Define the difference between direct- and indirect-reading sensors.
6. Calibrate sensors.
7. Measure the signal output of a sensor.
8. Define the following terms: limit switch, position indicator, level indicator, attitude indicator, tactile sensor, pressure sensor, temperature sensor.
10. Install and calibrate a sensor.
11. Interpret manufacturers' specifications.
12. Determine output signal characteristics for a variety of sensors.

LAB ACTIVITIES

1. Test seven types of sensors to determine output signal characteristics in relation to input signals.
2. Interpret manufacturers' specifications.
3. Install and calibrate thermal sensors in a heat transfer system.

CONTROLLERS FOR ROBOTS & AUTOMATED SYSTEMS

MODULE CA-01 Introduction to Controllers

INTRODUCTION

This module introduces students to the concept of devices/systems that control or sequence the operation of several pieces of equipment. It is the proper sequencing that is important to the successful operation of an automated system. Both open-loop (without feedback) and closed-loop (with feedback) controllers will be assembled and operated.

MODULE OUTLINE

I. Purpose/Function of Controllers

II. Open-Loop Control Principles
    A. Drum
    B. Stepper Motors
    C. Programmable Logic Controllers

III. Closed-Loop Control Principles
    A. Programmable Logic Controllers
    B. Proportional Robot Controller
        1. AC/DC servo
        2. Hydraulic
    C. Sensors
        1. Discrete
            a. Thermistor
            b. Photodiode
            c. Limit switch
            d. Hall effect
            e. Encoder
        2. Analog
            a. Piezoelectric
            b. Thermistor
            c. Phototransistor
            d. Strain gage rosette
            e. Thermocouple
            f. Acoustic
            g. Eddy current
            h. Potentiometer
            i. Resolver
            j. Tachometer generator

OBJECTIVES

Upon completion of this module students will be able to:

1. Describe the operation and the difference between open- and closed-loop controllers.
2. Identify the types of controllers in open-loop and closed-loop systems.

3. Describe the importance of sensors in a closed-loop control system.
4. Explain the function of a proportional robot controller.
5. List advantages and disadvantages of open-loop and closed-loop controllers.
6. Set up and operate an open-loop system that does not utilize sensors.
7. Set up and operate a closed-loop system with sensing.

MODULE CA-02 Open-Loop Controller Applications Fixed Sequence

INTRODUCTION

This module discusses open-loop controllers--those without feedback. Students will study, program and operate drum controllers, and stepper motors.

MODULE OUTLINE

I. Ladder Diagrams
   A. Logic Expressions
   B. Design

II. Drum Controller/Timer
   A. Programming
   B. Operations
   C. System Connection
   D. Reset/Start-up

III. Stepper Relay
   A. Relay Logic
   B. Inputs
   C. Programming
   D. Reset/Start-up
   E. System Connection

OBJECTIVES

Upon completion of this module students will be able to:

1. Program and operate drum controllers.
2. Describe typical devices and systems controlled by open-loop controllers.
3. Draw and interpret ladder diagrams.
4. Program and test a drum controller.
5. Install, replace, troubleshoot, repair or adjust to manufacturers' specifications, open-loop control devices.
6. Program and operate a stepper relay control.
7. Stop, reset and restart a system controlled by a stepper relay and/or drum controller.
8. Convert a ladder diagram into a drum controller program.
9. Explain relay logic.

LAB ACTIVITIES

1. Program and test a drum controller.
2. Install, adjust, troubleshoot and repair or replace open-loop control devices to manufacturer's specifications.
3. Program and operate a stepper relay control.
4. Stop, reset and restart a system controlled by a stepper relay and/or drum controller.
5. Draw ladder diagrams and convert them into drum controller programs.

CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS

Classroom/Laboratory hrs/wk 2/6

COURSE DESCRIPTION

Students will learn the principles of control systems and how they are applied to a production system to achieve automation. Systems included in the course are drum controllers, stepper motors, programmable logic controllers, microprocessors, computers, feedback systems and robot controllers.

COURSE OUTLINE

		Student Contact Hours	
		Class	Laboratory
I.	Introduction to Controllers	2	
	A. Purpose/Function of Controllers		
	B. Open-Loop Controllers		
	C. Closed-Loop Controllers		
II.	Fixed Sequence	8	18
	A. Ladder Diagrams		
	B. Drum Controllers/Timer		
	C. Stepper Relays		
III.	Programmable Logic Controllers (PLCs)	3	12
	A. Sequence Controller		
	B. Process Controller		
	C. Components/Architecture of PLC		
IV.	Feedback Sensors	3	15
	A. Discrete Signals/Sensors		
	B. Analog Signals/Sensors		
	C. Contact Sensors		
	D. Noncontact Sensors		
	E. Output Signal Uses		
V.	Robot Controllers	4	15
	A. Definition of a Manufacturing Operation		
	B. Sensing		
	C. Controller Programming		
	D. Operation		
	E. Robot Controller Programming--A Case Study		

STUDENT LABORATORIES

I. Set Up, Program and Operate Drum Controllers

II. Set Up, Program and Operate Stepper Motors/Relays

III. Set Up, Program and Operate Open- and Closed-Loop Programmable Logic Controllers

IV. Set Up, Calibrate and Operate Feedback Sensors and Control Devices Including Encoders and Resolvers

V. Set Up and Operate Robot Controllers using:
Teach pendants
Walk through
Off line
Post process

STUDENT COMPETENCIES

Upon completion of this course, the student will be able to:

1. Install, adjust, troubleshoot and repair or replace control devices to manufacturer's specifications.
2. Program stepper relays.
3. Program and/or reprogram PLCs (drum, relay and microprocessor types) for specific sequence of events.
   a. Prepare a flow chart for a specific sequence of events in performing a given application.
   b. Enter instructions into control unit.
   c. Run program to see if it executes properly.
   d. Edit or debug program as necessary.
   e. Download and upload programs.
   f. Recognize and resolve hardware/software impedance matching problems.
4. Draw logic diagrams.
5. Read, understand and comply with requirements of service bulletins.
6. Use teaching pendant for testing, editing and setup.
7. Adjust feedback loops that include:
   a. Encoders
   b. Optical sensors
   c. Electronic sensors
   d. Microprocessors
   e. Optoelectronics
   f. Hall-effect devices
   g. Velocity sensors
   h. Position detectors
8. Install a programmable controller and its input/output devices.
9. Perform electrical adjustments on servo power amplifiers.
10. Perform zeroing of encoders.
11. Define axis control and feedback specifications.

MODULE CA-03 Programmable Logic Controller

INTRODUCTION

Students will learn what programmable logic controllers (PLCs) are and how they are applied to controlling automated systems. Both sequence and process applications will be studied along with programming and interfacing the PLCs.

MODULE OUTLINE

I. Sequence Controller
   A. Programming
   B. Output Signals

II. Process Controller
   A. Programming
   B. I/O Signals

III. Components/Architecture of PLCs
   A. Processor
   B. Power Supply
   C. Memory
   D. I/O

OBJECTIVES

Upon completion of this module students will be able to:

1. Describe the difference between a sequence controller and a process controller.
2. Install, program and operate PLCs (sequence controller) by:
   a. Preparing a flow chart
   b. Entering instructions into control unit
   c. Running program
   d. Editing/debugging program
   e. Downloading/uploading program
   f. Recognizing and resolving hardware/software impedance matching problems
3. Install, program and operate PLCs (process controller) by:
   a. Preparing a flow chart
   b. Entering instructions into control unit
   c. Running program
   d. Editing/debugging program
   e. Downloading/uploading program
   f. Recognizing and resolving hardware/software impedance matching problems

4. Draw logic diagrams.
5. Explain how a programmable logic controller is used to control an automated system.
6. Interchange programmable logic controllers between machines.

LAB ACTIVITIES

1. Interchange programmable logic controllers between machines.
2. Program/reprogram PLCs for a specific sequence of events by:
   a. Preparing a flow chart
   b. Entering instructions into control unit
   c. Running program
   d. Editing/debugging program
   e. Downloading/uploading programs
   f. Recognizing and resolving hardware/software impedance matching problems

MODULE CA-04 Feedback Sensors and Control

INTRODUCTION

This module describes closed-loop control systems including feedback. The students will study and apply feedback (discrete) signals to controllers. Other items to be studied include encoders and resolvers.

MODULE OUTLINE

I. Discrete Signals/Sensors
   - A. Signal Characteristics
   - B. Input versus Output
   - C. Sensor Output

II. Analog Signals/Sensors
   - A. Signal Characteristics
   - B. Input versus Output
   - C. Sensor Output

III. Contact Sensors
   - A. Operation
   - B. Limitation

IV. Noncontact Sensors
   - A. Operation
   - B. Limitation

V. Output Signal Uses

OBJECTIVES

Upon completion of the module students will be able to:

1. Define feedback and its purpose.
2. Describe the operation of resolvers and encoders.
3. Adjust feedback loops that include:
   - a. Encoders
   - b. Optical sensors
   - c. Electronic sensors
   - d. Microprocessors
   - e. Optoelectronics
   - f. Hall-effect devices
   - g. Velocity sensors
   - h. Position detectors
4. Compare the advantages and disadvantages of contact and noncontact sensors.
5. Calibrate encoders and resolvers.
6. Install and calibrate noncontact sensors.
7. Install and calibrate contact sensors.

LAB ACTIVITIES

1. Calibrate encoders and resolvers.
2. Install, calibrate contact sensors.
3. Install, calibrate noncontact sensors.
4. Adjust feedback loops that include:
    a. Encoders
    b. Optical sensors
    c. Electronic sensors
    d. Microprocessors
    e. Optoelectronics
    f. Hall-effect devices
    g. Velocity sensors
    h. Position detectors

CONTROLLERS FOR ROBOTS & AUTOMATED SYSTEMS

MODULE CA-05 Robot Controllers

INTRODUCTION

This module introduces students to controllers whose programs can be easily changed. Students will reprogram controllers that operate automated systems to accomplish a wide variety of tasks. Signals will be fed back so that students can observe the interactive principles of sensing and controlling systems.

MODULE OUTLINE

I. Define a Manufacturing Operation
What Individual Tasks are Accomplished

II. Sensing
- A. Types of Sensors
- B. Information Sensed and Transmitted
- C. Robot Arm
  1. Position
  2. Velocity
- D. Work Cell
  1. Contact
  2. Noncontact
  3. Process

III. Controller Programming
- A. Architecture
- B. Fixed Logic (Fixed Sequence)
- C. Reprogrammable
- D. Languages
- E. Robot Programming--A Case Study

IV. Operation
- A. Mechanical
- B. Electrical
- C. Signals Sensed and Transmitted

V. Robot Controller Programming--A Case Study

OBJECTIVES

Upon completion of this module the student will be able to:

1. Draw ladder diagrams and construct working representative models.
2. Program robot controllers by:
   - a. Preparing flow chart
   - b. Entering instructions
   - c. Running program
   - d. Editing/debugging program
   - e. Downloading/uploading program
   - f. Resolving hardware/software problems

3. Program computers that control automated systems.
4. Program microprocessors that control automated systems.
5. Explain the advantage of being able to rapidly reprogram an automated system.
6. Explain the difference between microprocessors and computers.
7. Interchange robot controllers.
8. Determine input signals required for feedback.
9. Reprogram a controller so a robot performs a different function.
10. Adjust servo power amplifiers.
11. "Zero" an encoder.

LAB ACTIVITIES

1. Define input signals required (feedback) for an automated system controller.
2. Reprogram a controller so that a robot performs a different function.
3. Perform electrical adjustments on servo power amplifier.
4. Perform zeroing of an encoder.
5. Program controllers by:
   a. Preparing flow chart
   b. Entering instructions
   c. Running program
   d. Editing/debugging program
   e. Downloading/uploading program
   f. Resolving hardware/software problems

ROBOTICS/AUTOMATED SYSTEMS AT WORK
Classroom/Laboratory hrs/wk 2/6

COURSE DESCRIPTION

This course provides students an opportunity to observe and study the application of robots and automated systems to manufacturing. Students will simulate in the lab several of the systems observed in industry. The laboratory exercises are aimed at evaluating current systems and attempting to improve them.

COURSE OUTLINE	Student Contact Hours Class	Laboratory
I. Review Two Types of Automation A. Fixed B. Flexible	2	4 (field trips)
II. Flexible Automation A. Case Studies (Class) 1. Welding 2. Assembly 3. Material handling B. Case Study (Individual) Machine tending	10	42
III. Fixed Automation A. Case Studies (Class) 1. Bottlers 2. Transfer line 3. Photocopier B. Case Study (Individual) 1. Process control 2. Packaging	8	14

STUDENT LABORATORIES

1. Set up, debug, program, operate robots in two categories (electric, pneumatic, or hydraulic).
   a. Point-to-point, continuous path, control path
   b. Circular, spherical, cartesian, jointed spherical
   c. Drum, PLC, microprocessor, computer
2. Perform an analysis of an existing automated system.
3. Assemble prototype systems similar to existing production systems.

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

1. Install, adjust, troubleshoot and repair or replace sensors for tactile sensing.
2. Identify and use appropriate lubricant.

3. Use manual's troubleshooting charts to aid fault isolation/repair.
4. Explain the difference between accuracy, precision and repeatability.
5. Install, adjust, troubleshoot, repair or replace:
   a. Industrial robots
   b. End-of-arm tooling
   c. Smart actuators
6. Interconnect robots and other equipment.
7. Analyze and select appropriate robot sensing requirements for certain manufacturing operations.
8. Start up and debug a robot system.
9. Analyze operating difficulties of installed robots; perform necessary corrective adjustments to return system to normal operation.
10. Perform field testing of a robot and check to assure that its performance is in accordance with specifications.
11. Specify the robot-to-material interfaces.
12. Set up, etc., robot to either remove parts from transfer line and palletize them or to depalletize parts and place then on a transfer line.
13. Design a system for counting regular/irregular-shaped objects moving on an overhead track.
14. Operate the following equipment.
    a. End-of-arm tooling
    b. Grippers
    c. Magnetic pickups
    d. Vacuum pickups
    e. Compliance devices
15. Adapt the following to robotic application:
    a. Welder
    c. Paint sprayers
    b. Adhesive applicators
    d. Grinders
16. Adapt the following to work with automated systems:
    a. Conveyors
    b. Bulk feeders

MODULE RS-01 Review the Types of Automation

INTRODUCTION

This module is a brief review of the types of automated production--fixed and flexible. Students will compare the SME and Japanese definitions of robots and learn how each is applied to automation.

MODULE OUTLINE

I. Fixed (Hard) Automation
   A. In Line
   B. Rotary

II. Flexible Automation
   A. High-Volume/Low-Mix Products
   B. Low-Volume (Each)/High-Mix Products

OBJECTIVES

Upon completion of this module students will be able to:

1. State both the SME and Japanese definitions of a robot.
2. Explain the difference between the definitions.
3. Describe fixed automation.
4. Describe flexible automation.

MODULE RS-02 Flexible Welding

INTRODUCTION

Students will analyze a flexible welding system that is in use. One of the flexible production systems being investigated will be simulated in the laboratory. This will be a class project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Analyze a flexible automated welding system.
2. Assemble a prototype welding system similar to the operating system.
3. Program and operate the prototype system.
4. Select, install, and calibrate sensors used on the prototype system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

MODULE RS-03 Flexible Assembly

INTRODUCTION

Students will analyze a flexible assembly system that is in use. One of the flexible production systems being investigated will be simulated in the laboratory. This will be a class project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Analyze a flexible automated assembly system.
2. Assemble a prototype assembly system similar to the operating system.
3. Program and operate the prototype system.
4. Select, install, and calibrate sensors used on the prototype system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

MODULE RS-04 Flexible Material Handling

INTRODUCTION

Students will analyze a flexible material-handling system that is in use. One of the flexible production systems being investigated will be simulated in the laboratory. The system to be studied may be a large-scale system, such as a stacker, that includes wire-guided vehicles, or it may be a smaller-scale system that involves only one robot that palletizes/depalletizes parts. This will be a class project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Analyze a flexible automated material-handling system.
2. Assemble a prototype material-handling system similar to the operating system.
3. Program and operate the prototype system.
4. Select, install, and calibrate sensors used on the prototype system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

MODULE RS-05 Flexible Machine Tending

INTRODUCTION

Students will analyze a flexible machine-tending system that is in use. One of the flexible production systems being investigated will be simulated in the laboratory. This will be an individual project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Analyze a flexible automated machine-tending system.
2. Assemble a prototype machine-tending system similar to the operating system.
3. Program and operate the prototype system.
4. Select, install, and calibrate sensors used on the prototype system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

MODULE RS-06 Fixed (Hard) Automation--Bottling Plant

INTRODUCTION

Students will determine the operating principles and characteristics for a bottling plant. This will be a class project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Perform case studies on bottling plants.
2. Measure the performance of the power supplies, controllers and sensors in a fixed automation system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

ROBOTICS/AUTOMATED SYSTEMS AT WORK

MODULE RS-07 Fixed (Hard) Automation--Transfer Line

INTRODUCTION

Students will determine the operating principles and characteristics for a transfer line. This may involve either or both light-duty (light weight, small parts) or heavy-duty (heavy or large) lines. This will be a class project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Perform case studies on transfer lines.
2. Measure the performance of the power supplies, controllers and sensors in a fixed automation system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

MODULE RS-08 Fixed (Hard) Automation--Photocopier

INTRODUCTION

Students will determine the operating principles and characteristics for a photocopier. This will be a class project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Perform case studies on photocopiers.
2. Measure the performance of the power supplies, controllers and sensors in a fixed automation system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

ROBOTICS/AUTOMATED SYSTEMS AT WORK

MODULE RS-09 Fixed (Hard) Automation--Process Control System

INTRODUCTION

Students will determine the operating principles and characteristics for a process control system. This will be an individual project.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Perform case studies on process control systems.
2. Measure the performance of the power supplies, controllers and sensors in a fixed automation system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

ROBOTICS/AUTOMATED SYSTEMS AT WORK

MODULE RS-10 Fixed (Hard) Automation--Packaging

INTRODUCTION

Students will determine the operating principles and characteristics for a packaging operation.

MODULE OUTLINE

CASE STUDY
- Company (where study is being done)
- System to be studied
- Equipment involved (include an overall sketch)

FOR EACH MAJOR PIECE OF EQUIPMENT
- Item (name, manufacturer, model, serial number)
- Major operations performed
- Task breakdown (identify tasks performed)
- Power source/size (electric, hydraulic, ?)
- Control system (drum, programmable logic controller, microprocessor, computer)
- Programming language
- Sensors incorporated (temperature, pressure, position, ?)
- Application/economic justification

FOR ROBOTS
- Specification
- Type/classification
- Mounting (fixed, track, ?)
- Method of installing program
- Load capacity

OBJECTIVES

Upon completion of this module students will be able to:

1. Perform case studies on packaging operations.
2. Measure the performance of the power supplies, controllers and sensors in a fixed automation system.

LAB ACTIVITIES

1. Select power supplies, sensors, and transfer systems.
2. Design and assemble a controller system.
3. Program controllers.
4. Adjust, calibrate and operate the system.

ROBOTICS & AUTOMATED SYSTEMS INTERFACES
Classroom/Laboratory hrs/wk 2/6

COURSE DESCRIPTION

Students in this course will learn the principles of interconnecting (interfacing) controllers, sensors and actuators. They will study, set up and operate simple (discrete, binary) and complex (analog) sensors, tooling, controllers and network interfacing.

COURSE OUTLINE	Student Contact Hours Class	Laboratory
I. Simple Sensor Interfaces (Discrete, Binary) A. Sensors B. Controllers	4	12
II. Control Signal Interfacing A. Electrical Characteristics B. RS-232 Characteristics C. Data Transmission D. Terminology	4	12
III. Mechanical Interfaces A. Interchangeability B. Grippers C. Welders D. Applicators E. Grinders F. Lasers	4	12
IV. Electrical Interfaces A. Interchangeability B. Magnetic Pickups C. Grippers with Tactile Sensors D. Welders	4	12
V. Networking A. Data Exchange B. Control of Other Computers/Controllers	4	12

STUDENT LABORATORIES

1. Interface Signals
   a. Measure sensor output and compare to manufacturer's specifications.
   b. Simulate signals input to controller and observe and measure the response.
   c. Compare and analyze RS-232C interconnections and determine requirements for compatibility.

2. Tooling Interfaces
   a. Mechanical
      1. Interchangeability
      2. Movements/clearances
      3. Special hardware/tools of installation
   b. Electrical
      1. Power supplied
      2. Control signals
      3. Actuator/sensor sensing
      4. Disconnects
   c. Pneumatic/hydraulic
      1. Disconnects
      2. Pressure/volume flow
      3. Sensing

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

1. Use manual's troubleshooting charts to aid fault isolation/repair.
2. Use manufacturer's manuals as a guide to troubleshoot, repair, test and operate a failed machine.
3. Use manufacturer's manuals to determine a machine's normal operating characteristics.
4. Using a manual, identify operational/functional systems.
5. Disassemble, repair, test and return to service robots that have failed.
6. Install, adjust, troubleshoot, repair or replace:
   a. Industrial robots
   b. End-of-arm tooling
   c. Smart actuators
7. Coordinate the operation of several pieces of automatic equipment.
8. Adjust machines for accuracy and repeatability.
9. Start up and shut down an automated production system.
10. Follow troubleshooting procedures recommended by the manufacturer to diagnose, isolate and repair a robot/automated system.
11. Specify the robot-to-material interfaces.
12. Set up, program, troubleshoot a system comprised of a minimum of two transfer lines, one robot and at least one machining center.
13. Set up, and so forth, robot to either remove parts from a conveyor and palletize them or to depalletize parts and place them on a conveyor.
14. Configure a system for counting regular/irregular-shaped objects moving on an overhead track.
15. Operate the following equipment:
   a. End-of-arm tooling
   b. Grippers
   c. Magnetic pickups
   d. Vacuum pickups
   e. Compliance devices
16. Adapt the following to robotic application:
   a. Welder
   b. Adhesive applicators
   c. Paint sprayers
   d. Grinder

17. Adapt the following to work with automated systems:
    a. Conveyors
    b. Bulk feeders
18. Program a host computer to control several "lower-level" computers that in turn control portions of an automated system.
19. Interchange different open-loop controllers between systems.
20. Interchange different closed-loop controllers between systems.

ROBOTICS & AUTOMATED SYSTEMS INTERFACES

MODULE RI-01 Simple Sensor Interfaces (Discrete/Binary)

INTRODUCTION

This module introduces students to the principles and procedures of (electrically) interfacing controllers and sensors. Students will set up and measure the characteristics of transmitted and received signals.

MODULE OUTLINE

I. Sensors
   A. Sensor Outputs
      1. On/off
      2. High/low
   B. Sensor Mountings
      1. Structural
      2. Thermal
      3. Electrical
   C. Sensor Calibration
      Positioning
   D. Interconnect/Cabling
      1. Conductors
      2. Nonconductors (for example, fiber optics)

II. Controllers
   A. Programmable Logic Controllers
      1. Power supply
      2. Input signal requirements/characteristics (from sensor)
      3. Output signal requirements/characteristics (to control)
      4. Programming
   B. Robot Input/Output
      1. Input signal requirements/characteristics (from sensor)
      2. Output signal requirements/characteristics (to control)
      3. Programming
   C. Interconnects/Cabling
      1. Conductors
      2. Nonconductors

OBJECTIVES

Upon completion of this module students will be able to:

1. Define a discrete signal.
2. Measure interfacing requirements for transmitting and receiving a signal.
3. Set up interfaces between discrete sensors and controllers.
4. Measure discrete sensor output.
5. Measure signal insertion loss in fiber-optic cabling.

ROBOTICS & AUTOMATED SYSTEMS INTERFACES

MODULE RI-02 Control Signal Interfacing

INTRODUCTION

This module describes the characteristics of RS-232 interfacing requirements. Students will measure the characteristics of transmitted and received signals across an RS-232 connector.

MODULE OUTLINE

I. Electrical Characteristics
   A. Data Transmission
      1. Parallel
      2. Serial
   B. Synchronous Transmission
   C. Asynchronous Transmission

II. RS-232 Characteristics
   A. Voltage Levels
   B. Pin Configurations

III. Data Transmission
   A. Without Handshaking
   B. With Handshaking

IV. Terminology
   A. Half Duplex
   B. Full Duplex

OBJECTIVES

Upon completion of this module students will be able to:

1. State the difference between serial and parallel transmission.
2. Recall the advantages of serial transmission and when it would be preferred over parallel data transmission.
3. Recall when parallel transmission of data would be preferred over serial data transmission.
4. Write the voltage specifications of RS-232.
5. State RS-232 handshaking capability availability.

LAB ACTIVITIES

1. By using a computer program, output an ASCII character using an endless loop:
   a. Observe and record the output waveform
   b. Observe and record voltage level
   c. Observe and record dc offset

d. Observe and record frequency
e. Observe and record stop bit/start bit

Change the ASCII character and repeat the above measurements.

2. Demonstrate capability to interface a printer to a host computer. By using the pin diagram of the computer and printer, identify each pin used and its function.
3. Repeat #2 using a computer terminal-keyboard/CRT.

ROBOTICS & AUTOMATED SYSTEMS INTERFACES

MODULE RI-03 Mechanical Interfaces

INTRODUCTION

This module describes the physical characteristics of mounting different tools on a robotic arm. Students will evaluate the mounting characteristics of several types of robot arms.

MODULE OUTLINE

I. Interchangeability
   A. Locating Devices
   B. Clearances
   C. Tolerances
   D. Parallel/Squareness
   E. Coordinate System, Reference

II. Grippers
   A. Parallel
   B. Nonparallel

III. Welders
   A. Resistance
   B. Arc
   C. MIG
   D. TIG

IV. Applicators
   A. Adhesive
   B. Paint

V. Grinders

VI. Lasers

OBJECTIVES

Upon completion of this module students will be able to:

1. Write specifications for mechanical interfaces.
2. Interpret manufacturer's data to determine if a tool is adaptable to a specific robot arm and define the difference if it is not adaptable.
3. Specify robot-to-material interfaces.

LAB ACTIVITIES

1. Interchange the following equipment:
   - End-of-arm tooling
   - Grippers
   - Magnetic pickups
   - Vacuum pickups
   - Compliance devices
2. Adapt the following to robotic application:
   - Welders
   - Adhesive applicators
   - Paint sprayers
   - Grinders
3. Design and build mechanical alignment devices for use in mounting tooling on a robot arm.

MODULE RI-04 Electrical Interfaces

INTRODUCTION

This module describes the characteristics required to electrically interchange robot tooling. Students will evaluate three types of connectors used in designing interchangeable connectors.

MODULE OUTLINE

I. Interchangeability
   A. Connector Configuration
   B. Pin Configuration
   C. Voltage and Current Restraints

II. Magnetic Pickups

III. Grippers with Tactile Sensors

IV. Welders

OBJECTIVES

Upon completion of this module students will be able to:

1. Write specifications for electrical connectors.
2. Describe the proper application of three different connectors.
3. Evaluate manufacturer's specifications of connectors.

LAB ACTIVITIES

1. Adapt welders to robotic application
2. Specify mating electrical plugs and receptacles.
3. Modify circular connectors to prevent undesired connections.

ROBOTICS & AUTOMATED SYSTEMS INTERFACES

MODULE RI-05 Networking

INTRODUCTION

Students will interconnect microprocessors and computers so they can "talk" to each other. Computers will be interconnected forming a local area network. Methods of connecting a host computer to other computers that control portions of automated systems will be studied and simulated.

MODULE OUTLINE

I. Data Exchange
   A. RS-232 Interface
   B. Send/Receive

II. Control of Other Computers/Controllers
   A. Handshaking
   B. Control Signal Interchanging
   C. Use of Another Computer's Memory
   D. Hierarchy of Control
   E. Manufacturer's Automation Protocol (MAP)

OBJECTIVES

Upon completion of this module students will be able to:

1. Define the control systems necessary for computer-integrated manufacturing.
2. Coordinate the operation of several pieces of automatic equipment.

LAB ACTIVITIES

1. Program a host computer to control several "lower-level" computers.
2. Program several computers so they can address, input, and output information from the other computers.

AUTOMATED WORK CELL INTEGRATION
Classroom/Laboratory hrs/wk 1/8

COURSE DESCRIPTION

Students, working in teams and under the instructor's supervision, will assemble and operate an automated production system. The students will select equipment, write specifications, design fixtures and interconnects, integrate system/provide interfaces, and make the assigned system operational. This is a laboratory class.

COURSE OUTLINE	Student Contact Hours	
	Class	Laboratory
The instructor will assign a project similar to those described on the following pages. Students will analyze the requirements, write specifications and assemble, program, debug and operate a prototype or demonstration work cell.	10	80

STUDENT COMPETENCIES

Upon completion of this course, the student should be able to:

1. Interconnect robots and other equipment.
2. Program a host computer that controls the operation of several pieces of equipment.
3. Set up, operate, troubleshoot, maintain and repair automated systems.
4. Use manual's troubleshooting charts to aid fault isolation/repair.
5. Disassemble, repair, test and return to service robots that have failed.
6. Install, adjust, troubleshoot, repair or replace:
   a. Industrial robots
   b. End-of-arm tooling
   c. Smart actuators
7. Coordinate the operation of several pieces of automatic equipment.
8. Adjust machines for accuracy and repeatability.
9. Set up machine vision system.
10. Analyze and select appropriate robot sensing requirements for certain manufacturing operations.
11. Start up and shut down an automated production system.
12. Follow troubleshooting procedures recommended by the manufacturer to diagnose, isolate and repair a robot/automated system.
13. Perform field testing of a robot and check to assure that its performance is in accordance with specifications.
14. Develop material handling specifications for a work cell.
15. Set up, program, troubleshoot a system comprised of a minimum of two transfer lines, one robot and at least one machining center.
16. Set up, and so forth, robot to either remove parts from transfer line and palletize them or to depalletize parts and place them on a transfer line.
17. Program a host computer to control several "lower-level" computers that in turn control portions of an automated system.
18. Write material handling specifications for a work cell.

AUTOMATED WORK CELL INTEGRATION

INTRODUCTION

Students will work in small teams on assigned projects that include the design, specification writing, assembly, programming, debugging, and operation of assigned work cells. Students will then reprogram the controller and make other necessary adjustments so the same physical equipment will perform a different task.

MODULE OUTLINE

The instructor will assign one or more of the following projects. Students will analyze the requirements, write specifications, and assemble, program, debug and operate a prototype or demonstration work cell.

OBJECTIVES

Upon completion of this course students will be able to:

1. Convert work assignments into written specifications.
2. Design and assemble a reprogrammable work cell.
3. Program, debug, and operate the work cell.
4. Reprogram the work cell to accomplish different tasks.

LAB ACTIVITIES

The lab activities are outlined as projects on the following pages.

AUTOMATED WORK CELL INTEGRATION

TEAM MEMBER ASSIGNMENT

Students in each team will be rotated so that each has an opportunity to do all of the following jobs.

LEADER:
- Directs efforts of team members
- Directs assembly of equipment

RECORDER:
- Assists assembly
- Records decisions
- Sketches setups and parts
- Writes project report

SUPPLIER:
- Obtains needed parts
- Assists assembly
- Designs needed parts

PROGRAMMER:
- Assists assembly
- Writes/coordinates the programming
- Selects sensors
- Selects interconnecting cabling

PROJECT 1 PARTS PRODUCTION

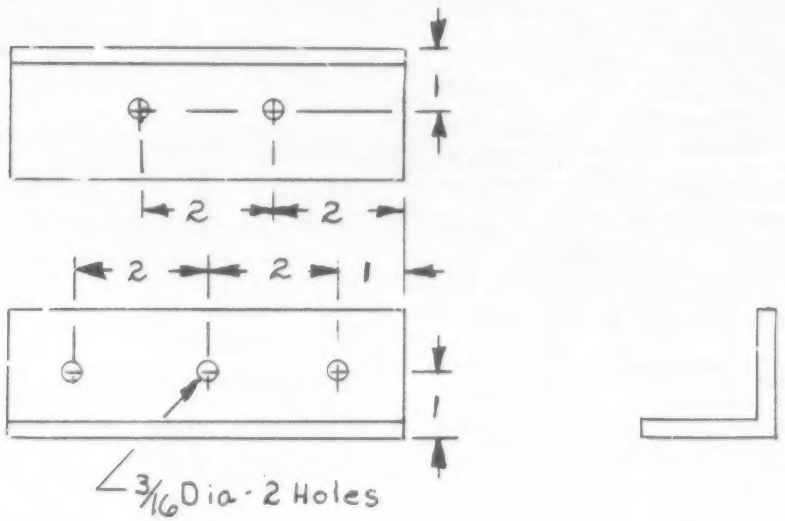
ASSIGNMENT

Automate the production of the part shown in the sketch. The major tasks to be accomplished are:

1. Load a 20' piece of 2x2x1/4 angle on an automatic cut-off saw.
2. Cut the angle into 6" lengths.
3. Drill holes per sketch.
4. Palletize the finished parts.

SUGGESTED EQUIPMENT TO BE AUTOMATED

1. Cut-off saw
2. One or two drill presses
3. Conveyor(s)



PROJECT 2 INSPECTION

ASSIGNMENT

Automate the separation of pieces of round bar stock according to length. Two lengths of parts will be supplied randomly. This project should not use vision.

SUGGESTED EQUIPMENT TO BE AUTOMATED

1. Conveyor
2. Inspection System
3. Palletizing

PROJECT 3 HEAT TREAT

ASSIGNMENT

Design, assemble, and operate an automated Heat Treating Work Cell. The major tasks to be accomplished include:

1. Remove the untreated part from the pallet.
2. Place part in heat treating oven.
3. When t = 850 degrees, remove the part from the oven.
4. Quench the part.
5. Place part on pallet.

SUGGESTED EQUIPMENT TO BE AUTOMATED

1. Conveyors
2. Oven
3. Pallets
4. Quenching

PROJECT 4 PALLETIZING

ASSIGNMENT

Automate the packaging of one-gallon paint cans in a cardboard box. Paint cans (empty) weigh approximately eight ounces. They will be supplied at a rate of four per minute.

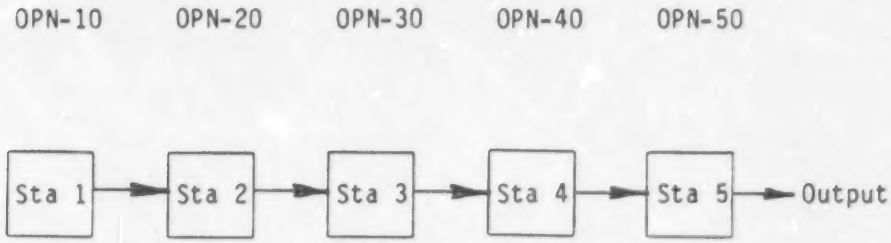
SUGGESTED EQUIPMENT TO BE AUTOMATED

1. Conveyor
2. Pick and place robot
3. Method to remove full boxes
4. Supply of boxes to be filled.

PROJECT 5 ASSEMBLY

ASSIGNMENT

Assemble a semicomplex product. Assembly (electric motor, etc.) of at least 15 different parts in a specified period of time to demonstrate the theory of mass production by allocating work to different assembly stations to attain the required production rate of "X" jobs per hour.



OBJECTIVE

1. To demonstrate task breakdown to attain a specific production rate.
2. To demonstrate the practicality of replacing manual labor with fixed or flexible automation.
3. As an added benefit to explain the justification parameters for replacing manual effort with mechanical devices.

Note: OPN-10 indicates oeprations to be conducted at Station 1.